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Retirement and cognitive reserve : A stochastic frontier approach applied to survey data

Stéphane Adam, Eric Bonsang, Sophie Germain and Sergio Perelman

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Retirement and cognitive reserve:
A stochastic frontier approach applied to survey data[1]

Stéphane Adam[1], Eric Bonsang[2], Sophie Germain[1] and Sergio Perelman[2]

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[1] Neuropsychology Unit, University of Liège, Belgium
[2]CREPP, HEC-Management School, University of Liège, Belgium

Abstract

This paper proposes the use of the stochastic frontier approach to analyse the relationship between cognitive performance, retirement and non-professional activities of the 50+ individuals using data from three surveys conducted in Europe (the Survey on Health, Ageing and Retirement in Europe and the English Longitudinal Survey on Ageing) and United States (the Health and Retirement Study). Next to the strong relationship between cognitive performance, age and education, this study highlights the negative effect of retirement and the positive impact of non-professional activities and social contacts.

Keywords: Cognitive reserve; Retirement; Stochastic Frontier

JEL classification: I12; J14; J26

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1. Introduction

Over the last decades, the age of retirement became a key variable in industrialized countries, especially in several European countries where early retirement is often considered by decision-makers, but also by most people, as the "natural" way to adjust labour market excess supply. The popularity of pre-retirement schemes, broadly defined to include disability, sickness and unemployment paths to retirement, is proved by the low employment rates reached among the 55-64 years old in most of these countries. Nevertheless, up to now no clear evidence was given that the massive withdraw of aged workers from the labour market favored the employment of other categories of the population. On the contrary, as shown by Blöndal and Scarpetta (1998) the reverse situation seems to occur as some of them, mainly Scandinavian countries, afford to keep most aged workers in activity at the same time they reached the higher employment rates in Europe for all the other categories of the population.

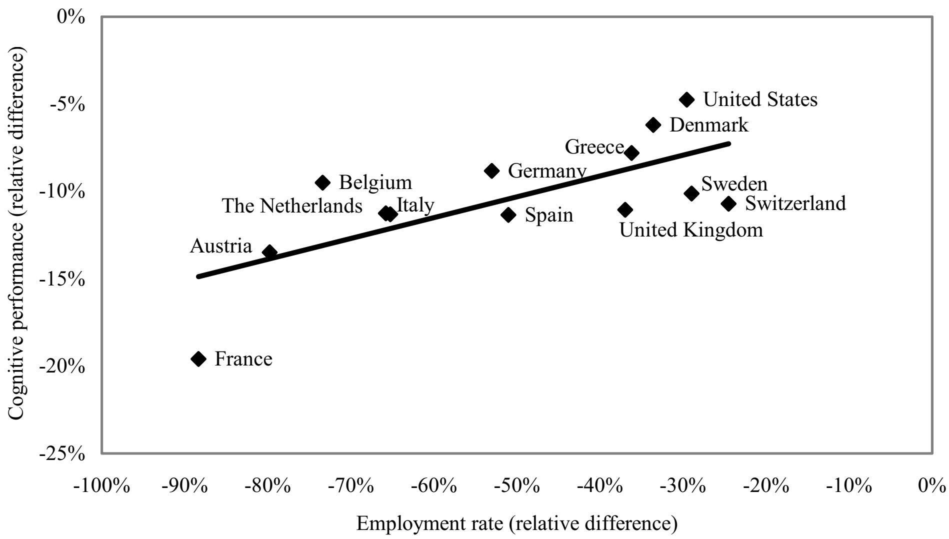
In this paper our concern is the population of retirees and a particular aspect of their well-being: the evolution of individual cognitive performances at retirement. For this purpose, we rely on the broad neuroscience literature that shows how occupational activities play a positive role on cognitive performances and in particular on the constitution of the so-called "cognitive reserve" described recently by Stern (2002, 2003). The cognitive reserve concept emerges from the repeated observations that there is not a direct relationship between the severity of the factor that disrupts performance (such as degree of brain pathology or brain damage) and the degree of disruption in performance. It suggests that some individuals are able to use more efficiently their cognitive resources and thus are less susceptible to disruption. Individual heterogeneity can stem from innate or genetic differences, or different life experience such as occupational attainement or leisure activities (Stern, 2003). Retirement implies many changes in the lifestyle of the elderly, which may in turn affect cognitive reserve and thus cognitive performances at older age.

The potential role of the age of retirement in the economy was originally underlined in the life-cycle model proposed by Ando and Modigliani (1963), but it was the extension of this model developed by Feldstein (1974) that for the first time introduced the notion of endogenous retirement decisions and the potential effect on them created by Social Security regulations. Nowadays, mainly thanks to the NBER International Social Security project (Gruber and Wise, 1999, 2004), we know that this is the case. Public, as well as in some cases private, pension schemes regulations create incentives that influence individual decisions to withdraw anticipatively from the labour market. Other than the potential drawbacks of early retirement on labour markets efficiency and for the long-term sustainability of pay-as-you-go schemes, there is another drawback that cannot be neglected, its potential impact on individuals'cognitive performances.

This research is today possible thanks to the data collected on the "50 and +" population by three interdisciplinary survey projects: the Health and Retirement Study (HRS), started in the United States in 1992; the English Longitudinal Study on Ageing (ELSA), started in United Kingdom in 2002; and the Survey on Health, Ageing and Retirement in Europe (SHARE), whose first wave took place in 2004 in several other European countries. These surveys include information on many aspects of life, including work, financial situation, family, housing, physical and mental health. They allow to analyse many dimensions of the ageing process and constitute a powerful tool to identify the factors driving cognitive performance and more particularly the effect of labour force participation on their individual cognitive reserve.

Figure 1 illustrates what must be considered as the starting point of our research. On the horizontal axis we report the percentage points slowdown in employment rates when we compare the 50-54 to the 60-64 years old groups in HRS, ELSA and SHARE countries and, on the vertical axis, the slowdown in cognitive performances, measured by a ten-words two-recall memory test, between the same age groups within the same countries. Even if this rough crossing-age groups comparison suffers of several potential bias, mainly due to an underlying steady-state assumption, it highlights what we consider as the main evidence of a potential unexpected consequence of early retirement programs. Without anticipating the results of a detailed statistical study, as that presented here, it appears that countries that performed better in terms of labour market participation among the elderly, also seem to have better prevented cognitive capacity decline.

Figure 1. Employment rate and cognitive performances. Relative difference between 60-64 and 50-54 years old men



Source: ELSA for United Kingdom, HRS, for United States, and SHARE for the other countries. 2004.

For estimation purposes, we use a parametric stochastic frontier approach (SFA). This approach, which was originally developed to measure firms' performances in an output-input setting, has been applied to measure individual performances in other fields of human behavior in which measurable outcomes, e.g. well-being and education, are driven by observable factors.[2] In this study, we use the SFA to estimate the individual efficiency of cognitive functioning, measured by memory tests scores.[3] For this purpose, a composed error term model is estimated using econometric tools. On the one hand, we assume that a normally and symmetrically distributed error term catch random noise, and, on the other hand, that an asymmetrically (truncated) normally distributed error term represents individuals' distance to the frontier, also known as technical inefficiency in the frontier analysis literature. Within this framework, the frontier corresponds to the best cognitive functioning that individuals are expected to reach if they were fully efficient. This benchmark is assumed to mainly depend on biological factors, such as age and memory-related diseases, education, and other control variables. Technical efficiency can then be interpreted as a measure of cognitive reserve: the higher the cognitive efficiency, the

[2] See, for instance, applications to households' well-being in Lovell et al. (1994) and to students' performances in Perelman and Santin (2005).

[3] Stochastic frontier analysis was introduced contemporaneously by Aigner et al. (1977) and Meusen and Van den Broeck (1978). For a complete survey, see Kumbhakar and Lovell (2002) or Coelli et al. (2005).

higher the cognitive reserve. The stochastic frontier model specification proposed by Battese and Coelli (1995) allows to test the effects of factors such as retirement, social and non-professional activities on individual cognitive efficiency.

Results confirm the hypothesis that social interactions and occupational activities, including paid-work and not paid-work as well as sport practice and other physical activities contribute to the constitution of the cognitive reserve.

The next sections of the paper are organized as follows. In Section 1 the cognitive reserve concept is presented, as well as a condensed survey of studies in the field. Section 2 is devoted to the presentation of the SFA approach and Section 3 to the samples and variable definitions. In Section 4 the main results of the study are reported and, finally, Section 5 summarizes the conclusions.

2. The "cognitive reserve" concept

Over the past 25 years, a great deal of evidences have been accumulated indicating that advancing age is accompanied by systematic decline in performance on a wide variety of cognitive tasks. However, although this cognitive decline with age has been defined, this process is not unavoidable. There exist many examples of elderly people who keep high cognitive functions, even at extreme age. Fillit et al. (2002) suggested that individuals have varying degrees of « functional reserve » in their brains. Persons with high functional reserve may have increased capacity to keep learning and adapting despite age-related changes (Baltes and Baltes, 1990). This view has been developed in more functional terms by Stern (2002 and 2003) and Scarmeas and Stern (2003) with the concept of "cognitive reserve". For Scarmeas and Stern (2003), cognitive reserve related back to the fact that innate intelligence or aspects of life experience like educational or occupational attainments provide a reserve, in the form of a set of skills or repertoires that allows some people to prevent cognitive decline associated with normal aging or Alzheimer's disease. A related idea is that there may be differences in how individuals compensate once the pathology disrupts the brain network that underlie performance. Cognitive reserve could take the form of using brain networks or cognitive paradigms that are more efficient or flexible, and thus less susceptible to disruption. In essence, an individual who uses a brain network more efficiently, or is more capable of calling up alternate brain networks or cognitive strategies in response to increased demand may have more cognitive reserve and might maintain effective performance longer in the face of brain pathology (Stern, 2003).

Recent researches tried to identify parameters contributing to the development of cognitive reserve. For example, education is largely recognized as having an impact on cognitive functioning, and is thought to support the cognitive reserve capacity (e.g. Le Carret et al., 2003). Some studies confirming this idea have suggested that people with a high educational level have lower risk of developing dementia compared to people with a low educational level (Letenneur et al., 1999; Stern et al., 1994). Similarly, lower linguistic ability in early life (Snowdon et al., 1996) and lower mental ability scores in childhood (Whalley et al., 2000) appeared to be strong predictors of poor cognitive function and dementia at older age.

Factors other than IQ and education might also provide reserve and influence the cognitive functioning of elderly people. So, several studies have suggested that differential susceptibility to age-related cognitive decline or to Alzheimer's disease is related to variables, such as: occupation (Evans et al., 1993; Letenneur et al., 1994; Schooler et al., 1999; Stern et al., 1994), professional or leisure activities (Carpuso et al., 2000; Scarmeas et al., 2001; Wilson et al., 2002), and life style (see for a review: Fillit et al., 2002; and Fratiglioni et al., 2004); variables which have been therefore considered as associated with cognitive reserve.

All these findings on cognitive reserve may have important implications for the structure of retirement. Keeping occupational activities as far as possible may contribute to maintain cognitive functioning in old age.

3. The stochastic frontier approach

According to the cognitive reserve concept, individuals with high cognitive reserve reach a higher level of cognitive functioning for a given level of cognitive resources. Such a reserve allows to delay or decrease the loss of cognitive functioning due to the biological ageing process or illnesses. It suggests that high cognitive reserve allows to use more efficiently cognitive resources. The aim of the empirical model is to analyse the effects of retirement, and other non-professional activities, on the constitution of the cognitive reserve. The stochastic frontier approach provides a useful tool to measure cognitive reserve. Indeed, this approach allows to measure cognitive functioning (measured by a score based on cognitive test) that individuals would reach if they were fully efficient for a given level of resources. This method allows to calculate a efficiency ratio, which may be interpreted as a measure of cognitive reserve. Ideally, the frontier would include factors influencing biological resources of the individuals. However, we choose to include education, which is usually associated with cognitive reserve, as determinants of the cognitive frontier to take into account the interdependent relationship between cognitive ageing and education. As a result, cognitive resources are assumed to depend mainly on biological factors such as age and other memory-related diseases, education, and other control variables such as, gender, ethnicity, country dummies… The model can be described as follows: [$ln\, r_i = f(X_i, D_i) + \varepsilon_i$] (1); where r_i is the cognitive test score of individual i, X_i is a vector containing the two main determinants of cognitive functions (i.e., age and education), aside with a vector of control variables, D_i, and ε_i is a composed error term of the form: [$\varepsilon_i = v_i - u_i$] (2); where v_i is assumed to be a two-sided random (stochastic) disturbance term to account for statistical noise, distributed iid $N(0, \sigma_v^2)$ and independent of X_i, and u_i a random term assumed to be independently distributed as truncations at zero of the $N(\varphi_i, \sigma_u^2)$ distribution.[4]

The u_i term has a key interpretation in the frontier analysis literature; it corresponds to the distance to the best practice- represented by the stochastic frontier$[f(X_i, D_i) + v_i]$. In the case analysed here, the best practice would correspond to the maximum cognitive functions each individual is expected to reach given his age and years of education. Note that u_i appears additively in the equation after the logarithmic transformation of the dependent variable, which means that $exp(-u_i)$ corresponds to the individual efficiency ratio and is equal to 1 when the individual cognitive performance lies on the frontier.

We opt for a translogarithmic specification for the relation between the cognitive performances, and the age and education in equation (1). The proposed function corresponds to a second order approximation on these two variables aside with $d_{m,i}$ (m=1,2,…,M) control variables such as gender and country dummies. The function to be estimated is the following:

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4 Both terms are independently distributed $(\sigma_{uv} = 0)$.

$$ln\, r_i = \beta_0 + \beta_1 ln\, x_{1,i} + \beta_2 ln\, x_{2,i} + \beta_3 (ln\, x_{1,i})^2 + \beta_4 (ln\, x_{2,i})^2 + \beta_5 (ln\, x_{1,i})(ln\, x_{2,i})$$
$$+ \sum_{m=1}^{M} \lambda_m D_{m,i} + v_i - u_i \quad (3),$$

where β_k (k=0,1,…,5) and λ_m (m=1,2,…,M) are parameters to be estimated. The main advantage of the translog specification is its great flexibility. Other than the logarithmic transformation of variables, second order terms allow for non-linear relations and interactions among age and education. The derivative of this function at each point corresponds to the rate of substitution between age and education. In other words, it estimates how many years of cognitive ageing are compensated by an additional year of education, measured at different ages and levels of education.

Moreover, the SFA model specification proposed by Battese and Coelli (1995) allows to test simultaneously the influence of other individual characteristics, denoted by J variables $z_{j,i}$, on cognitive performances u_i, through the truncation parameter: [$\varphi_i = \delta_0 + \sum_{j=1}^{J} \delta_j z_{j,i}$] (4). The z-variables include individual characteristics such as employment status, non-professional activities and social interactions. The δ_0 and δ_j are parameters to be estimated jointly with the β_k and λ_m parameters in equation (4) using a maximum likelihood optimization algorithm.[5] In addition, two other parameters are simultaneously estimated: $\sigma_\varepsilon^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma_\varepsilon^2$, the last term corresponding to the share of inefficiency on total error term variance. The expected efficiency ratio for the i[th] observation is obtained as follows:

$$E(exp(-u_i)|\varepsilon = e_i) = \left\{ exp\left(-\mu_i * + \frac{1}{2}\sigma^2 * \right) \right\} \left\{ \frac{\Phi\left((\mu_i * / \sigma^2 *) - \sigma^2 * \right)}{\Phi\left(\mu_i * / \sigma^2 * \right)} \right\} , \qquad (5)$$

$$\mu_i * = \frac{\sigma_v^2 z_i \delta - \sigma_u^2 e_i}{\sigma_v^2 + \sigma_u^2}, \; \sigma^2 * = \frac{\sigma_u^2 \sigma_v^2}{\sigma_v^2 + \sigma_u^2}.$$

5 For estimations we use FRONTIER Version 4.1, a program developed by Coelli (1994).

4. Data

4.1. The surveys: ELSA, HRS and SHARE

Our analysis uses three surveys on older individuals in Europe and United-States: the English Longitudinal Survey of Ageing (ELSA), the Health and Retirement Study (HRS), and the Survey of Health, Ageing and Retirement in Europe (SHARE). These surveys include a wide range of information about health, employment, financial situation, the family and activity of the 50+ populations.

ELSA is a survey based on a representative sample of individuals born in or before 1952 living in private households in England. The sample is drawn from households that had previously participated to the Health Survey for England (HSE) during 1998, 1999 and 2001. In this paper, we use the second wave of ELSA that has been conducted during 2004/2005.[6]

HRS is a survey conducted by the Institute for Social Research at the University of Michigan and includes a nationally representative panel of older Americans every two years since 1992. The HRS has followed a sample of individuals born between 1931 and 1941 and their partner since 1992. From 1998 onwards, this survey also included respondents from the Asset and Health Dynamics Among the Oldest Old (AHEAD) study (born between 1890 and 1923), a representative sample of individuals born between 1924 and 1930 (the Children of the Depression Age) and between 1942 and 1947 (the War Baby Cohort). An additional sample of individuals born between 1948 and 1953 (the Early Baby Boomers) has been added in 2004. As a result, the seventh wave (2004) of HRS includes individuals born on 1953 or before. The RAND Corporation provides a user-friendly version of the HRS data that was partly used in this analysis. This study uses the seventh wave of HRS conducted during 2004.[7]

SHARE is a European multi-disciplinary survey including more than 30,000 persons born in 1954 or before, and coming from 11 European countries ranging from Scandinavia

[6] More information about the survey is available in the ELSA website: http://www.ifs.org.uk/elsa/
[7] More information on the data and the methodology can be found in the HRS website: http://hrsonline.isr.umich.edu/

to the Mediterranean, and Israel.[8] We use in this paper the release 2 of the first wave of the survey, which was conducted in 2004.The data were collected using a computer assisted personal interviewing (CAPI) program, supplemented by a self-completion paper and pencil questionnaire. For more details on the sampling procedure, questionnaire contents and fieldwork methodology, readers should refer to Börsch-Supan et al. (2005).[9]

The good coordination between these three surveys allows comparing the results across them. A high proportion of the questions asked to the respondents are the same for each survey.

4.2. The dependent variable: the memory test score

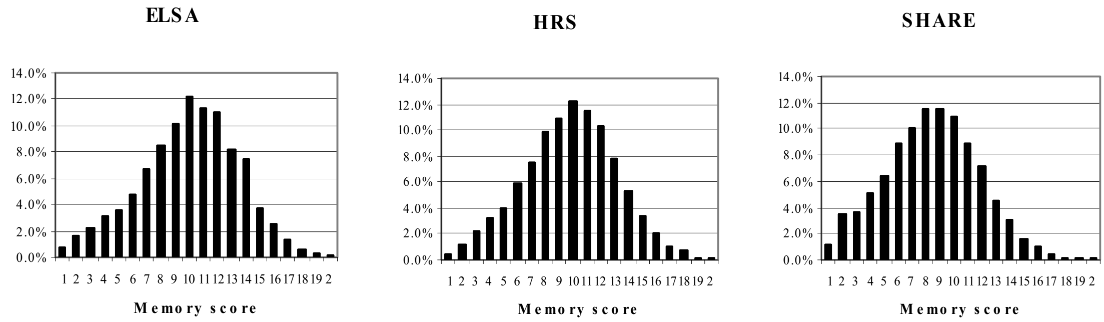
The three surveys contain measures of cognitive functioning based on simple tests. This study focuses on one key cognitive domain: episodic memory. This type of memory allows to stock and recover events that we have experienced (it can be what we had for dinner two days ago or a list of words to learn and remember in a psychological test) or information learnt in a specific spatial or temporal context (for example, the last holidays, the movie watched a few days ago, or the discussion with friends at the last dinner). The rationale underlying this choice was twofold: from a psychometric point of view, we selected a sensitive cognitive score that is not affected by ceiling or floor effects (excess of maximum or minimum values). From a more theoretical point of view, it is widely recognized that episodic memory is a cognitive domains that is particularly sensitive to cognitive ageing. In fact, some authors consider that episodic memory is among the first cognitive functions to decline with age (Anderson and Craik, 2000; Prull et al.,2000). The related task integrated in the three surveys consisted in a test of verbal learning and recall, where the participant is required to learn a list of ten common words: The interviewer first reads a list of ten common nouns to the respondent, and asked the respondent to recall as many words as possible from the list in any order. After approximatively 5 minutes of asking other survey questions, the respondent was asked to recall again the list of words previously read to him/her. Memory score for this task was calculated by adding the number of target words recalled at the immediate recall phase with the number of target words recalled at

[8] The first wave of SHARE data includes twelve countries: Austria (AU), Belgium (BE), Germany (DE), Denmark (DK), France (FR), Greece (GR), Italy (IT), Netherlands (NL), Spain (ES), Sweden (SE), Switzerland (CH) and Israel (IL).

[9] More information on the SHARE website: http://www.share-project.org/

the delayed recall phase (score ranging from 1 to 20). Observations reporting a memory score of zero are excluded from the analysis because we suspect that this result is partly due to survey mistakes, outliers, or individuals with particularly severe cognitive impairements. HRS and ELSA contain four lists of ten words (that are the same across the two surveys) and respondents are randomly assigned a list of words to learn. For SHARE, there is only one list of words for all individuals and the list of words is different from ELSA and HRS. This difference makes cognitive performances comparison across surveys difficult if different lists of words are more or less easy to learn.[10] However, we are not directly interested in comparing cognitive score across surveys but in analysing the relative effects of different factors on the cognitive performances. Figure 2 presents the distribution of memory score by survey. The distribution of the memory score seems to follow a normal distribution around 10 for ELSA and HRS while it is around 8 and 9 for SHARE.

Figure 2. The distribution of memory score.



4.3. The explanatory variables

As mentioned in the Section 1, the two main variables assumed to determine cognitive performances are age (x_1) and years of education (x_2). Minimum age is 50 year-old in SHARE and HRS but 51 for ELSA 2004 as it follows a representative sample of individuals born on or before 1952. Note also that age is censored at 90 year-old for ELSA observations. As we don't have the information about their true age, we drop these individuals from the ELSA sample. The computation of the years of education variable is slightly different across surveys. Years of education are constructed for the different SHARE-participating countries according to the 1997 International Standard Classification

[10] Note that we found significant differences in the cognitive score obtained from the different lists of words randomly assigned to individuals from HRS and ELSA.

of Education (ISCED-97) (OECD, 1999). In ELSA, the variable is constructed on the basis of the question that asks the respondent when he stopped full-time education. The answer to this question is categorical and can only take the following categories: 1. Not yet finished[11]; 2. Never went to school; 3. 14 or under; 4. At 15; 5. At 16; 6. At 17; 7. At 18 and 8. 19 or over. The years of education variable is computed assuming that education starts at 6 year-old, that those having left school at 14 or before have completed 6 years of education and that those having stopped at 19 or over have 15 years of education. Finally, HRS uses the following question "What is the highest grade of school or year of college you completed?" to compute the years of education variable. Note that those having more than 17 years of education are recorded as having 17 years of education. For the analysis, we drop individuals reporting no education in the ELSA sample. These individuals account only for 24 observations in the sample. A more careful analysis of these observations revealed that these individuals are quite different from the other low-educated individuals. They have a significantly higher memory score and are wealthier. Moreover, a high proportion of these individuals are born outside the country. We prefer to drop these individuals from the analysis as they account for a very small proportion of individuals in the sample. Note that we performed the same analysis on individuals with no education in HRS and SHARE but their characteristics better matched to the other low-educated individuals although they seems to perform slightly better than individuals with very low education.[12] Note also that, as we use the translog specification for the stochastic frontier, we have to add one unit to the variable years of education to avoid the "problem of the logarithm of zero" for individuals with no education.

Next to age and years of education, several dummy variables are integrated into the model as controls (D_i). First, we include country dummies in SHARE model. They are expected to catch differences across countries that may be the result of language and cultural differences. Other controls are dummy variables corresponding to women and to individuals born outside the country. Ethnicity is also included as control variable in the HRS sample. We also include a series of dummy variables, corresponding to the individual's position in his country's wealth distribution: second, third and fourth quartiles, respectively (first quartile as reference group). Differences in cognitive test scores due to

[11] Individuals with the answer "not yet finished" are drop from the analysis.
[12] Note that individuals with no education are concentrated in France, Spain and Greece in the SHARE sample.

gender, origin or wealth position cannot be considered to be representative of cognitive reserve differences but are the consequence of particular life circumstances. We also take into account several health-related variables that are likely to affect the cognitive ability. For SHARE, we include dummies that indicate whether the respondent has had a stroke, whether he has the Parkinson's disease, whether he takes drugs for anxiety or depression, whether he has a brain cancer or whether he has ever been institutionalised in a psychiatric institution. For ELSA, we control for stroke, Parkinson's disease and dementia. HRS includes variables related to stroke and to the fact that the individual has or has had psychiatric problems. A dummy variable indicates that the respondent suffers from at least two chronic diseases among a list of diseases including high blood pressure, cholesterol, diabetes, asthma, osteoporosis, arthritis, etc. The list of chronic diseases slightly differs across surveys. The Appendix describes them in details. Mental health is measured by a binary variable indicating whether the individual suffers from depression symptoms. For SHARE, this indicator is built on the basis of the EURO-D scale of depression, which takes into account depression symptoms such as pessimism, suicidal tendencies, guilt, sleeping disorders, interest, irritability, and so on (Prince et al., 1999a, 1999b). ELSA and HRS uses the Center for Epidemiologic Studies Depression Scale (CES-D).[13] The binary variable is equal to 1 if the corresponding depression scale is higher than 3.

Next, we selected several indicators that may potentially explain individual cognitive efficiency (these indicators correspond to z_j variables). These variables encompass several characteristics related to activities, professional or not, and social interactions. First, work and retirement status are represented by five dummy variables, where "being employed or self-employed" is the reference category: "being retired within 5 years", "being retired within 5 to 10 years", "being retired within 10 to 15 years", "being retired for more than 15 years", and "having never worked". These variables are constructed using the question about the employment status of the respondent and the question that asks to the non-working individuals when they left their last job, if any. Second, several variables highlight the involvement of the respondents in other non-professional activities. These characteristics are represented by a dummy variable indicating whether the individual is engaged in non-professional activities. The list of the non-professional activities is different across the three surveys. The Appendix defines the complete list of them for each

[13] See Irwin et al (1999) for more information about the CES-D and its validity.

Table 1. Summary statistics.

	ELSA	HRS	SHARE
Memory score	10.0	9.8	8.3
Age	66.1	66.9	64.4
Years of education	9.7	12.5	10.1
<u>Country:</u>			
AT	-	-	6.9%
BE	-	-	13.5%
DK	-	-	6.0%
FR	-	-	10.4%
DE	-	-	10.9%
GR	-	-	9.8%
IT	-	-	9.3%
NL	-	-	10.3%
ES	-	-	8.3%
SE	-	-	11.0%
CH	-	-	3.5%
Woman	55.2%	59.2%	54.3%
Born out of the country	6.0%	10.0%	7.7%
Born out of the country missing	0.7%	-	-
Black	-	14.0%	-
Other	-	4.7%	-
Chronic disease	44.4%	56.5%	40.2%
<u>Health:</u>			
Depression symptoms	15.2%	19.6%	24.1%
Depression symptoms *missing*	0.8%	-	-
Stroke	4.7%	6.5%	3.4%
Parkinson	0.6%	-	0.5%
Drugs for anxiety or depression	-	-	5.4%
Brain cancer	-	-	0.1%
Has been in psychiatric institution	-	-	2.3%
Psychiatric problem	-	15.5%	-
Dementia	0.5%	-	-
Nonprofessional activity	74.3%	34.6%	51.6%
Nonprofessional activity *missing*	15.7%	-	-
Mobility limitation	58.6%	68.6%	47.8%
<u>Physical activity:</u>			
Vigorous activity	38.6%	38.7%	59.4%
Moderate activity	83.0%	79.1%	89.6%
Single household	25.5%	23.9%	20.8%
Isolate	-	25.7%	-
Isolate missing	-	1.0%	-
<u>Work and retirement:</u>			
Working	35.1%	38.4%	32.7%
Retired within 5 years	12.5%	15.1%	9.7%
Retired within 5 and 10 years	13.0%	13.4%	12.1%
Retired within 10 and 15 years	12.8%	9.5%	11.0%
Retired since more than 15 years	22.9%	17.0%	22.1%
Never worked	1.5%	3.5%	8.7%
Retirement duration missing	2.2%	3.2%	3.7%
Number of observations	8,431	17,097	25,916

of them. Moreover, we include dummies related to the practice of vigourous physical activities and the practice of physical activities that require a low or moderate level of energy such as gardening, cleaning the car, or going for a walk. Finally, a dummy variable indicates whether the individual suffers from at least one mobility limitation in doing everyday activities such as walking 100 meters, sitting for about two hours, climbing several flights of stairs without resting, etc. The Appendix describes the complete list of mobility limitations. Third, we include a binary variable for single-person households. For the HRS, we also include a dummy (isolate) equal to one if the respondent reports that he almost never gets together with people in or near the facility\any of his neighbours just to chat or for a social visit. These indicators are expected to capture the effect of social isolation on cognitive reserve.

For explanatory variables having a non-negligible proportion of missing value, we computed an additional modality that control for it in the model, softening the potential selectivity bias that may arise in such cases. This additional category has been created for the following variables: born out of the country, depression symptoms, non-professional activity, social isolation, work and retirement.

Table 1 presents the means of the variables used in the model for each survey. The final ELSA sample contains 8,431 observations; the HRS sample includes 17,097 individuals and the SHARE sample size is 25,916.

5. Results

Table 2 presents the results of the stochastic frontier estimations corresponding to the three surveys: ELSA, HRS and SHARE. Results are strongly consistent across surveys. Almost all parameter estimates have the same sign across samples. As expected, the parameters related to education and age are significant, with the only exceptions being the age and education cross-effect in the model using ELSA. The parameters of this cross-effect are positive and significant for HRS and SHARE indicating that the relative decline in cognitive performances due to ageing is faster for individuals with a lower level of education. For example, it can be calculated from these results that the cognitive performances are expected to decrease by 5.8% from 60 to 70 year-old for an individual with the highest level of education in the HRS while this decline reaches 9.8% for those having the lowest level of education. Figure 3 illustrates the stochastic frontiers according to age and education for the three surveys. The shape of the frontiers according to age and education highlights the strong relationship between cognitive reserve, age and education. As expected, the cognitive frontiers decrease with respect to age at an increasing rate for the three models. Moreover, the higher the education level, the higher the cognitive frontier. Finally, the translog specification allows computing the marginal rate of substitution between age and years of education. One additional year of education for an individual being 60 year-old and having 10 years of education prevents the cognitive ageing by 3.0, 3.3 and 5.3 years for SHARE, ELSA and HRS respectively.

In most cases, the parameters on control variables are significant indicating that, as expected, they are important. Some results are worth noting: for example, results for the three surveys indicate that women perform better in terms of cognitive score than men. Moreover, wealthier individuals have a significantly higher score. For the SHARE data, it is worth noting that Spain and Italy are countries where the cognitive score is the lowest while Sweden and Switzerland obtain the highest one. To summarise, these estimated frontiers can be considered as a good benchmark with respect to which individual cognitive efficiency can be assessed.

Therefore, most of our attention will focus on the parameters presented at Table 3. They correspond to the z_j variables considered as potential factors related to activities and social isolation affecting individuals' cognitive efficiency or, in other words, distances to the estimated frontier. Note that negative amounts indicate less distance to the frontier or better cognitive functions, while positive signs indicate worse cognitive performances.

All the δ_j parameters are statistically significant and their signs correspond to our expectations. Clearly, all types of occupational activities, professional or otherwise, have a positive effect on the constitution of a cognitive reserve. In addition, vigourous or moderate physical activity appears to favor cognitive performances according to the three surveys while social isolation has a negative effect.

Results of the stochastic frontier clearly indicate that retirement decreases significantly cognitive reserve. The longer the individual is retired, the lower the efficiency. These results hold for the three surveys used in this paper. It is worth noting that respondents having never worked have the lowest cognitive efficiency.

The parameter estimates allow us to calculate the individual cognitive efficiency ratio

Table 2. The stochastic frontier parameters.

		ELSA		HRS		SHARE	
		Coef	(t-ratio)	Coef	(t-ratio)	Coef	(t-ratio)
Intercept	β_0	-5.419	(-1.9)	-23.616*	(-15.6)	-10.742*	(-6.7)
ln(age)	β_1	4.675*	(3.6)	13.082*	(18.8)	7.147*	(9.5)
ln(years of education)	β_2	-0.945*	(-2.0)	-0.567*	(-3.3)	-0.782*	(-7.5)
ln²(age)	β_3	-0.649*	(-4.4)	-1.648*	(-20.2)	-0.970*	(-10.8)
ln²(years of education)	β_4	0.129*	(3.5)	0.095*	(13.7)	0.065*	(17.8)
ln(years of education)*ln(age)	β_5	0.129	(1.4)	0.097*	(2.4)	0.171*	(7.2)
Country:							
AT		-		-		Ref	
BE	λ_1	-		-		-0.046*	(-4.8)
DK	λ_2	-		-		0.018	(1.6)
FR	λ_3	-		-		-0.053*	(-5.1)
DE	λ_4	-		-		-0.015	(-1.5)
GR	λ_5	-		-		-0.034*	(-3.2)
IT	λ_6	-		-		-0.122*	(-11.3)
NL	λ_7	-		-		0.017	(1.7)
ES	λ_8	-		-		-0.171*	(-15.2)
SE	λ_9	-		-		0.046*	(4.7)
CH	λ_{10}	-		-		0.029*	(2.2)
Woman	λ_{11}	0.081*	(14.0)	0.116*	(26.6)	0.099*	(23.3)
Born out of the country	λ_{12}	-0.080*	(-6.4)	-0.025*	(-3.3)	-0.050*	(-6.6)
Born out of the country missing	λ_{13}	-0.094*	(-2.8)	-		-	
Black	λ_{14}	-		-0.102*	(-16.1)	-	
Other	λ_{15}	-		-0.060*	(-5.8)	-	
Chronic disease	λ_{16}	0.000	(0.0)	-0.004	(-0.9)	0.006	(1.4)
Wealth quartile:							
1st wealth quartile		Ref		Ref		Ref	
2nd wealth quartile	λ_{17}	0.034*	(4.1)	0.025*	(4.1)	0.021*	(3.7)
3rd wealth quartile	λ_{18}	0.046*	(5.4)	0.042*	(6.5)	0.037*	(6.3)
4th wealth quartile	λ_{19}	0.065*	(7.4)	0.059*	(8.8)	0.037*	(6.2)
Health:							
Depression symptoms	λ_{20}	-0.019*	(-2.1)	-0.020*	(-3.3)	-0.046*	(-8.9)
Depression symptoms *missing*	λ_{21}	-0.016	(-0.5)	-		-	
Stroke	λ_{22}	-0.025	(-1.7)	-0.041*	(-4.5)	-0.039*	(-3.4)
Parkinson	λ_{23}	-0.073	(-1.8)	-		-0.042	(-1.5)
Drugs for anxiety or depression	λ_{24}	-		-		-0.016	(-1.7)
Brain cancer	λ_{25}	-		-		-0.038	(-0.5)
Has been in psychiatric institution	λ_{26}	-		-		-0.016	(-1.2)
Psychiatric problem	λ_{27}	-		-0.016*	(-2.5)	-	
Dementia	λ_{23}	-0.104*	(-2.4)	-		-	
Sigma		4.249*	(5.9)	2.468*	(11.1)	2.412*	(8.4)
Gamma		0.995*	(1,145.7)	0.988*	(933.2)	0.985*	(572.1)

Note:* means that parameter estimates are significant at the 5-percent level.

Figure 3: The stochastic frontiers according to age and years of education.

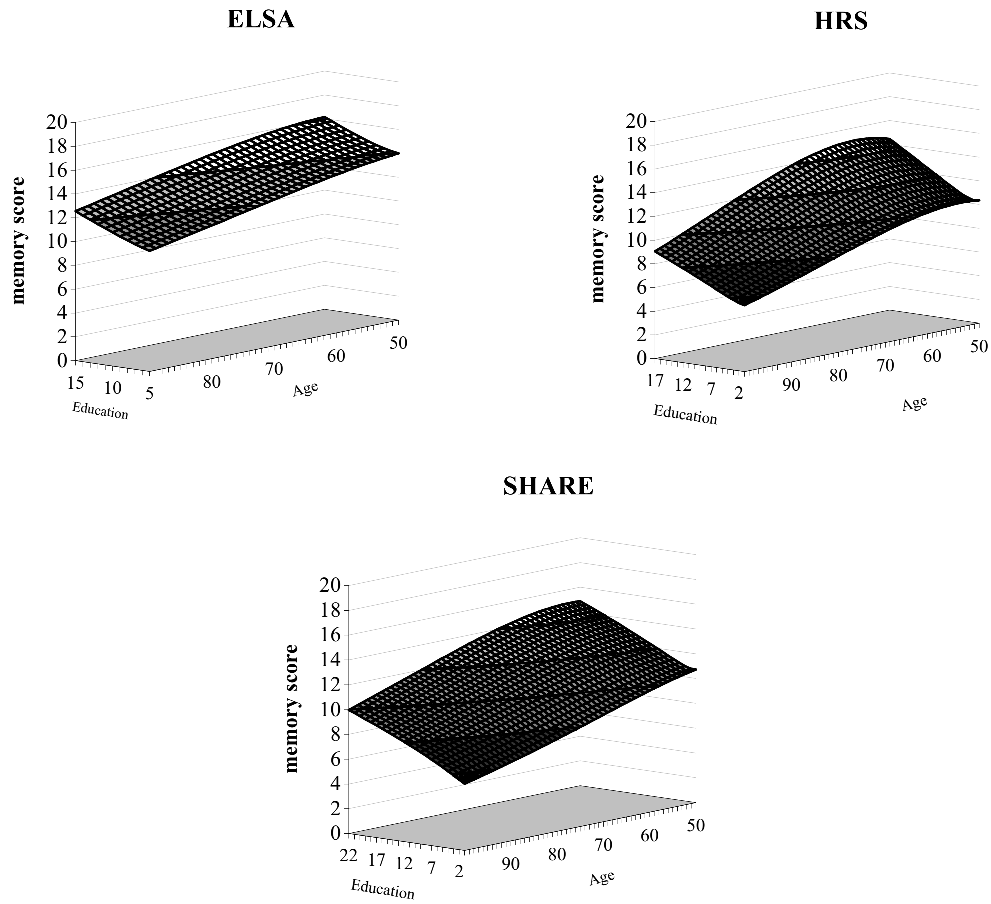


Table 3. The effects of activities on cognitive efficiency.

		ELSA		HRS		SHARE	
		Coef	(t-ratio)	Coef	(t-ratio)	Coef	(t-ratio)
Intercept	δ_0	-11.56*	(-5.2)	-8.91*	(-10.0)	-4.97*	(-6.9)
Nonprofessional activity	δ_1	-2.053*	(-5.3)	-2.122*	(-11.5)	-1.193*	(-8.5)
Nonprofessional activity *missing*	δ_2	1.731*	(5.4)	-		-	
Mobility limitation	δ_3	0.166*	(3.3)	0.058*	(2.8)	0.354*	(8.5)
<u>Physical activity:</u>							
Vigorous activity	δ_4	-1.246*	(-4.2)	-0.979*	(-9.8)	-0.918*	(-7.8)
Moderate activity	δ_5	-2.037*	(-6.8)	-0.830*	(-11.2)	-0.903*	(-8.6)
Single household	δ_6	0.404*	(9.1)	0.377*	(12.9)	0.579*	(8.6)
Isolate	δ_7	-		0.401*	(10.5)	-	
Isolate missing	δ_8	-		0.104	(0.9)	-	
<u>Work and retirement:</u>							
Working		Ref		Ref		Ref	
Retired within 5 years	δ_9	2.552*	(5.2)	2.709*	(10.8)	0.735*	(6.8)
Retired within 5 and 10 years	δ_{10}	3.139*	(5.0)	3.606*	(11.1)	1.281*	(8.0)
Retired within 10 and 15 years	δ_{11}	3.758*	(4.9)	4.449*	(11.6)	1.503*	(8.4)
Retired since more than 15 years	δ_{12}	5.781*	(5.6)	4.759*	(12.0)	2.191*	(9.6)
Never worked	δ_{13}	6.917*	(6.0)	5.066*	(11.7)	2.474*	(9.7)
Retirement duration missing	δ_{14}	5.247*	(5.4)	4.499*	(11.3)	2.956*	(9.6)

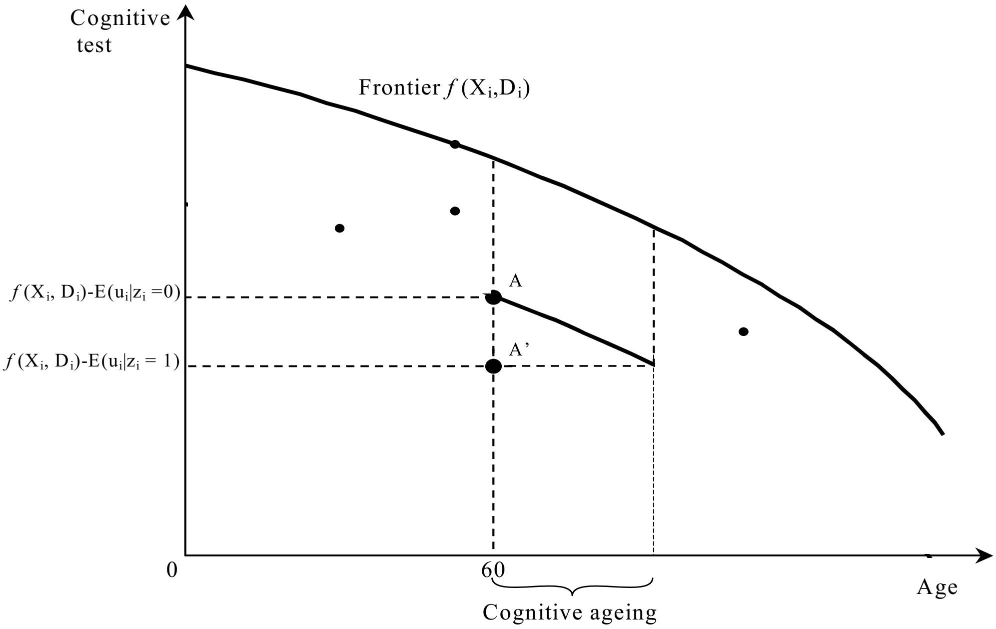
Note:* means that parameter estimates are significant at the 5-percent level.

Figure 4: Average efficiency ratio by age category across surveys.

using equation (5) for the three surveys. The average individual efficiency ratio is equal to 73.9% for ELSA, 76.5% for HRS, and 71% for SHARE. As shown in Figure 4, the average efficiency ratio decreases with age for the three surveys, this decline being stronger among ELSA respondents. The average efficiency ratio for 50-54 year old individuals is equal to 80%, 81%, and 76% for ELSA, HRS and SHARE respectively while it is equal to 57%, 67%, and 57% for 85-89 year old respondents. These results suggest that observed cognitive performances declines with age for two reasons: one is the normal cognitive ageing process represented by the frontier while the other is due to decreasing cognitive efficiency with age. Among others, retirement, non-professional activities, and social isolation partly explain this efficiency loss.

In order to quantify the effect of the z_i variables on cognitive capacity, we present in Table 4 the results of a simulation performed on the base of the 60-year-old individuals interviewed in ELSA, HRS and SHARE respectively. The outcome of this simulation is estimated in terms of cognitive aging, in other words, in years of cognitive decline. These estimates were calculated in two steps using the parameters presented in Tables 2 and 3. Figure 5 illustrates the computation of the cognitive ageing relative to the z_i variables assuming that its effect on cognitive efficiency is negative. Point A represents the cognitive performance of a 60 year-old individual assuming that the z_i variable is equal to 0 (the single household dummy for example) and point A' is the cognitive performance of the same individual assuming the z_i variable is equal to 1. For each individual, we calculated his/her cognitive performance change, corresponding to a change in a specific z characteristic, all other characteristics being equal. It is represented by the difference

Figure 5. The computation of the cognitive ageing due to the effect of the z-variables



between A and A' in Figure 5. The cognitive ageing due to the change of the z-variable is defined as the number of years of "normal" ageing corresponding to the cognitive decline due to the z-variable. For example, a 60-years-old individual retired for less than five years has the same cognitive performance as a 61.01 year-old working individual according to SHARE, 61.46 year-old according to ELSA and 63.90 year-old according to HRS. Similarly, an individual performing a non-professional activity delays his/her cognitive ageing by 1.6 years for SHARE, 1.18 for ELSA, and 3.18 for HRS. These results suggest that taking part in non-professional activities at retirement might compensate the cognitive loss due to retirement.

Note that the heterogeneity of these results across surveys depends on both the effect of retirement on "cognitive efficiency" and the shape of the cognitive frontier with respect to age around the age of 60. These results are thus not directly comparable across surveys. For example, the higher effect of retirement in term of cognitive ageing for HRS is explained by two factors: First, the estimated cognitive decline due to "normal" ageing is slower for HRS respondents compared to ELSA and SHARE individuals around the age of 60. The cognitive frontier for the average individual only decreases by 2.3% from 60 to 65 year-old while it declines by 3.0% for ELSA and by 3.6% in SHARE. As a result, even if the effect of retirement on cognitive performances was the same across surveys, it would give different results in term of cognitive ageing. Second, it can be calculated that the efficiency loss due to retirement is higher among HRS respondents. For a representative 60 year-old individual, the relative efficiency loss due to retirement is estimated at 1.5% for HRS, 0.7% for ELSA and 0.6% for SHARE.

Table 4. The effect of activities in terms of cognitive ageing.

	Cognitive ageing (in years)		
	ELSA	HRS	SHARE
Activities:			
Non-professional activity	-1.18	-3.18	-1.60
Moderate physical activity	-1.17	-1.54	-1.23
Vigorous physical activity:	-0.72	-1.75	-1.25
Mobility limitations	0.10	0.14	0.49
Work and retirement:			
Working	-	-	-
Retired within 5 years	1.46	3.90	1.01
Retired within 5 and 10 years	1.78	4.84	1.72
Retired within 10 and 15 years	2.13	5.67	2.01
Retired since more than 15 years	3.22	5.96	2.86
Never worked	3.83	6.25	3.21
Social isolation:			
Single household	0.24	0.78	0.80
Isolate	-	0.82	-

Note however that these results hold only if the identifying assumptions are valid, which include no correlation between the explanatory variables and the unobserved heterogeneity. It might not be the case if retirement and cognitive ability are endogenous: cognitive ability may affect the retirement decision. If it is true, the estimated effect of retirement on cognitive performances is likely to be overestimated. In addition, unobserved individual heterogeneity may be correlated to both retirement and cognitive performances: unskilled workers are likely to retire at an early age and obtain a lower cognitive score. In this case, the model would overestimate the effect of retirement on cognitive ability.

6. Conclusion

In this paper, we propose the use of a parametric stochastic frontier approach (Aigner et al., 1977; Meeusen & Van den Broeck, 1977) to study the impact of potential factors, including retirement and retirement duration, on cognitive functions among the population aged 50 and over in Europe and United States. More specifically, we focus on one key aspect of cognitive ability: episodic memory assessed by a test of words learning and recall. This cognitive function is particularly relevant for this study as episodic memory is among the first to decline with ageing. For this purpose, we used individual data collected in 2004 during the second wave of ELSA for United Kingdom, the seventh wave of HRS for United States and the first wave of SHARE (Börsch-Supan et al., 2005) for continental European countries. The multidisciplinary nature of these surveys allows us to simultaneously analyze several dimensions of participants' lives: physical and mental health, mobility, occupational activities, and socioeconomic status, in addition to cognitive performances.

As expected, our results show that cognitive performances is mainly driven by age (negatively, which refers to cognitive aging; for a review, see Buckner, 2004) and by years of education (positively). This second result is clearly in accordance with studies suggesting that education is one of the major factors contributing to the development of the cognitive reserve (Le Carret et al., 2003, 2005; Liao et al., 2005). In addition, except for the ELSA sample, the relative cognitive decline due to "normal" ageing seems to be faster for individuals with low education. Taking into account these effects of age and education, we use the SFA (Kumbhakar & Knox Lovell, 2002) to create a "frontier" corresponding to the optimum cognitive functioning that each individual is expected to achieve given his/her age and education level. This model then allows us to test simultaneously the effect of different factors (associated directly or indirectly with the notion of "general activity") that potentially drive cognitive efficiency and therefore contribute to the formation of individuals' cognitive reserve. Our results show that, after controlling the side effects of some factors not associated with the notion of "activity" (such as gender, being born inside or outside the country, and suffering from a chronic disease), all types of occupational activities clearly have a positive effect on cognitive reserve constitution. More specifically, individuals being retired for a longer period have a lower cognitive efficiency. In addition, non-professional activity preserves individuals from the cognitive ageing.

The policy implication of such results is straightforward: increasing the age of retirement is not only desirable to insure the viability of the retirement schemes but it could also delay the cognitive decline preventing the occurrence of the associated impairments at older age.

Acknowledgments

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Appendix

This appendix describes in more details some variables that differ across the three surveys.

Chronic diseases:

The dummy variable is equal to one when the individual report having at least two of the following conditions.

SHARE:

- A heart attack including myocardial infarction or coronary thrombosis or any other heart problem including congestive heart failure
- High blood pressure or hypertension
- High blood cholesterol
- Diabetes or high blood sugar
- Chronic lung disease such as chronic bronchitis or emphysema
- Asthma
- Arthritis, including osteoarthritis, or rheumatism
- Osteoporosis
- Cancer or malignant tumour, including leukaemia or lympho ma, but excluding minor skin cancers
- Stomach or duodenal ulcer, peptic ulcer
- Cataracts
- Hip fracture or femoral fracture

ELSA:

- High blood pressure or hypertension
- Heart problem (angina, heart attack (including myocardial infarction or coronary Thrombosis), congestive heart failure, a heart murmur, an abnormal heart rhythm)
- Diabetes or high blood sugar
- Chronic lung disease such as chronic bronchitis or emphysema
- Asthma
- Arthritis
- Osteoporosis
- Cancer
- Cataract
- Hip fracture

HRS:

- High blood pressure
- Diabetes
- Cancer, excluding skin
- Lung disease
- Heart condition
- Arthritis

Non-professional activity:

SHARE:

This variable is equal to 1 if the individual reports having done at least one of the following activities during last month:

- Done voluntary or charity work.
- Cared for a sick or disabled adult.
- Provided help to family. friends or neighbors.
- Attended an educational or training course.
- Gone to a sport. social or other kind of club.
- Taken part in a religious organization (church. synagogue. mosque. etc.).
- Taken part in a political or community-related organization.

ELSA:

This variable is equal to 1 if the individual reports having done at least one of the following activities during last month:

- Voluntary work
- Cared for a sick or disabled adult
- Looked after home or family
- Attended a formal educational or training course
- Political party, trade union or environmental groups
- Tenants groups, resident groups, Neighbourhood watch
- Church or other religious groups
- Charitable associations
- Education, arts or music groups or evening classes
- Social Clubs
- Sports clubs, gyms, exercise classes
- Any other organisations, clubs or societies

HRS:

This variable is based on the following question:

Have you spent any time in the past 12 months doing volunteer work for religious, educational, health-related or other charitable organizations?

Mobility limitations:

This dummy variable is equal to one if the individual reports having problems with more than one of the following actions:

<u>SHARE, ELSA, and HRS:</u>

-Walking 100 metres (yards/block).
-Sitting for about two hours.
-Getting up from a chair after sitting for long periods.
-Climbing several flights of stairs without resting.
-Climbing one flight of stairs without resting.
-Stooping. kneeling or crouching.
-Reaching or extending your arms above shoulder level.
-Pulling or pushing large objects like a living room chair.
-Lifting or carrying weights over 10 pounds/5 kilos. like a heavy bag of groceries.
-Picking up a small coin from a table.

Boulevard du Rectorat, 7 - Bât. B31 - 4000 Liège

Rue Louvrex, 14 - Bât. N1 - 4000 Liège

Belgium

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